SPECIFICATION

STRUCTURE FOR ADJUSTING WAVEFORMS OF OPTICAL FILTERS USED IN A DENSE WAVELENGTH DIVISION MULTIPLEXING SYSTEM AND METHOD OF ADJUSTING SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001]   The present invention relates to adjusting waveforms of optical filters used in Dense Wavelength Division Multiplexing (DWDM) systems, and more particularly to adjusting wavelengths of optical filters used in DWDM systems to obtain desired transmission and reflection.

2. The Prior Art

[0002]   Demand for increased transmission capacity in fiber optical communications systems is unrelenting.   Conventional transmission technology is increasingly unable to satisfy demands for higher transmission capacity and speed. Dense Wavelength Division Multiplexing (DWDM) technology has helped satisfy demand, and is now in widespread use in optical communications throughout the world.   A DWDM system multiplexes a plurality of signals of different wavelengths into single optical fiber at an initial end of the optical fiber.   The multiplexed signals are then demultiplexed into a plurality of different optical fibers at a terminal end.   Each demultiplexed signal is then output to the end recipient. DW DM systems can increase transmission capacity by ten times or more.   The heart of the transmission technology of DWDM systems is multiplexing many signals having different wavelengths into one fiber, and then

demultiplexing the multiplexed signals into a plurality of different fibers. The device that achieves this function is a multiplexer/demultiplexer.

[0003]   Nowadays there is a variety of multiplexer/demultiplexers in use, including multi-dielectric thin film filters, diffraction gratings, fiber bragg gratings (FBGs) and arrayed waveguide gratings (AWGs). Multi-dielectric thin film filters can achieve low insertion loss and high isolation of the multiplexer/demultiplexer. Multi-dielectric thin film filters also enjoy low production costs and established technology, and are therefore in widespread use.

[0004]   Figs. 1A, 1B, 2A and 2B show two conventional DWDMs using multi-dielectric thin film filters as the basic wave division device. Referring to Figs. 1A and 1B, the wave division device comprises a biporose pigtail 51, a gradient index (GRIN) lens 52 and a filter 53 glued on one end of the GRIN lens 52. The biporose pigtail 51 is usually made from a glass rod or other suitable body, and typically has two holes defined therein. Multiplexed signals are transmitted to the GRIN lens 52 through an input fiber 54 inside the biporose pigtail 51. The GRIN lens 52 acts as a convergent lens by converting the multiplexed signals to parallel or near-parallel light, and then transmits the light to the input surface of the filter 53. The filter 53 is pre-formed such that it allows only one specific wavelength λ_m to be transmitted therethrough, and reflects all other wavelengths. The reflected signals are then converged by the GRIN Lens 52 to enter a return optical fiber 55. The wavelength signal specific to the filter 53 is separated from the multiplexed signals, and transmitted to an output optical fiber (not shown). The input and return optical fibers 54, 55 are symmetrically disposed on opposite sides of a central longitudinal axis of the biporose pigtail 51. Therefore, the reflected signals from the GRIN lens 52 can be completely input into the return optical fiber 55.

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[0005]   Referring to Figs. 2A and 2B, the wave division device comprises a biporose pigtail 61, a GRIN lens 62 and a filter 63 glued on one end of the GRIN lens 62. Input and return optical fibers 64, 65 are disposed together in a single hole defined in a central longitudinal axis of the biporose pigtail 61

[0006]   In both these conventional DWDMs, a face of the GRIN lens 52, 62 that is joined to the filter 53, 63 is at a right angle to a central longitudinal axis of the GRIN lens 52, 62. 32-channel conventional DWDM systems are already in commercial use, and the center-wavelength bandwidth is now as small as 0.8 nm or even 0.4 nm. Therefore it is very important to accurately set the center-wavelength of a particular DWDM. Even a minute error in setting of the center-wavelength results in serious consequences such as channel cross talk and failure of transmission to the end recipient. With current technology, precisely setting a particular center-wavelength is very problematic. This is made all the worse because the face of the GRIN lens 52, 62 that is joined to the filter 53, 63 is at a right angle to the central longitudinal axis of the GRIN lens 52, 62; as a result the center-wavelength will be unable to be adjusted, and then the filter will be a no good (NG); unfortunately the case as described above often happens. So it greatly increases the production cost and reduces the efficiency of manufacture.

[0007]   In addition, manufacturing error such as thickness of layers of the filter may cause the transmitting center wavelength thereof slightly incorrect; however, there is no means for balancing or compensating the incorrect of the transmitting center wavelength of the filter in the prior art.

SUMMARY OF THE INVENTION

[0008] To solve the problems of the prior art, the present invention provides a structure for adjusting waveforms of optical filters used in a DWDM system comprises a filter, a GRIN lens and a biporose pigtail with two holes therein. The holes are parallel to a center-axis of the pigtail but at different distance from the center-axis thereof, an input and return optical fiber are secured within the two holes. The GRIN lens is provided with a first end coupled with the biporose pigtail; thus, signals from the input fiber can input the lens and the reflected signals from the lens can enter into the return fiber. The GRIN lens further defines a second end angularly to the axis thereof. The filter transmits determined wavelength and is joined with the second end of the GRIN lens.

[0009] In addition, the present invention more provides a method for adjusting waveforms of optical filters used in a DWDM system comprising steps as followed: measuring the actual center-wavelength of the filter; determining a difference between the actual center-wavelength and a desired center-wavelength of the filter; determining an angle γ of the second end of the GRIN lens and distances r_1, r_2 of the two hoes from the center optical axis of the pigtail that will yield the desired center-wavelength; grinding the second end of the GRIN lens to obtain the determined angle γ and forming the pigtail to obtain the determined distances r_1, r_2; adhering the filter to the second end of the GRIN lens; and integrating the formed pigtail with the combination of the filter and the GRIN lens.

[0010] Accordingly, an object of the present invention is to provide a structure and method of adjusting waveforms of optical filters used in a DWDM system which decreases production costs and increases production yields.

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[0011]   Another object of the present invention is to provide a structure and method of adjusting waveforms of optical filters used in a DWDM system which freely balances the uncorrectable transmitting center wavelength of the filter.

[0012]   Other objects, advantages and novel features of the present invention will be apparent from the following detailed description of preferred embodiments thereof with reference to the attached drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]   Fig. 1A is a schematic side view of a conventional multiplexer/demultiplexer having a filter;

[0014]   Fig. 1B is a cross-sectional view taken along line IB-IB of Fig. 1A;

[0015]   Fig. 2A is another schematic side view of another conventional multiplexer/demultiplexer having a filter;

[0016]   Fig. 2B is a cross-sectional view taken along line IIB-IIB of Fig. 2A;

[0017]   Fig. 3 is a diagram of optical operation of a filter in accordance with the present invention.

[0018]   Fig. 4A is a schematic side view of a multiplexer/demultiplexer having a filter, in accordance with the present invention.

[0019]   Fig. 4B is a cross-sectional view taken along line IVB-IVB of Fig. 4A;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020]   Fig. 3 is a working view of a filter 3 in accordance with a preferred embodiment of the present invention.   In the preferred embodiment, the filter 3 is

a thin film filter and works as follows. When a multiplexed incident optical signal 5 comprising different optical signals $\lambda_1, \lambda_2 ... \lambda_{\theta-1}, \lambda_\theta, \lambda_{\theta+1} ... \lambda_n$ enters a surface of the filter 3, the optical signal having the wavelength λ_θ is transmitted through and output by the filter 3 as optical signal 7. However, the other optical signals $\lambda_1, \lambda_2 ... \lambda_{\theta-1}, \lambda_{\theta+1} ... \lambda_n$ are reflected by the filter 3 as optical beam 6. λ_θ is the transmission center-wavelength of the filter 3.

[0021]   The filter 3 has a normal 9 defined through a center thereof. An angle of incidence θ is defined between the normal 9 and a direction of travel of the optical signal 5. Transmission spectrums of the thin film filter 3 vary according to the angle θ. Assuming that the transmission center-wavelength of the filter 3 is λ_0 when the angle $\theta = 0$, then a relationship of the transmission center-wavelength λ_θ and the angle θ can be described by the followed equation:

$$\lambda_\theta = \lambda_0 (1 - a \times \sin 2\theta)$$

wherein 'a' is a constant, a value of which is determined by a refractive index of a dielectric film of the filter 3.

[0022]   Turning to Fig. 4, a structure of adjusting a waveform of the filter being used in a Dense Wavelength Division Multiplexing (DWDM) system of the present invention comprises four parts: a pigtail 1, a graded index (GRIN) lens 2, a filter 3, and input and return optical fibers 41, 42. Two holes are defined in the pigtail 1, for accommodating the input and return optical fibers 41, 42 therein. The holes are parallel to and at respective opposite sides of a center longitudinal axis of the pigtail 1. One hole is spaced a distance r_1 from the center axis of the pigtail 1, and the other hole is spaced a distance r_2 from the center axis of the pigtail 1. r_1 and r_2 are not the same, therefore the holes are asymmetrically spaced from the center axis of the pigtail 1. The input and return optical fibers 41, 42 are secured

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in the pigtail 1 by means such as gluing. A first end 11 of the pigtail 1 is contiguous with and coupled to a first end 21 of the GRIN Lens 2. An angle α is defined between the first end 11 and a line perpendicular to the center axis of the pigtail 1. An angle β is defined between the first end 21 and a line perpendicular to the center axis of the pigtail 1. In the preferred embodiment, each angle α, β is between approximately 6 and 8 degrees for increasing the return loss. The GRIN Lens 2 has a second end 22 opposite to the first end 21. An angle γ is defined between the second end 22 and a line perpendicular to the center axis of the pigtail 1. The filter 3 is joined with the second end 22 of the GRIN lens 2 by means such as gluing.

[0023] After the multiplexed optical signal comprising different wavelengths $\lambda_1 \ldots \lambda_m \ldots \lambda_n$ has entered the input optical fiber 41 and been transmitted to the GRIN lens 2, the multiplexed signal is converged by the GRIN lens 2 to reach the surface of the filter 3 at an angle θ (not shown in FIG. 4A). A value of the angle θ is predetermined by the difference between the actual center-wavelength and a desired center-wavelength of the filter 3. The wavelength λ_m corresponding to the equation $\lambda_m = \lambda_0 (1 - a \times \sin 2\theta)$ is transmitted through the filter 3. The other wavelengths $\lambda_1 \ldots \lambda_{m-1} \lambda_{m+1} \ldots \lambda_n$ are reflected by the filter 3. This reflected optical signal enters the GRIN lens 2, and is converged by the GRIN lens 2 into the return optical fiber 42.

[0024] In a particular application, a filter 3 is required to transmit a center-wavelength having a particular value. One method for attaining such filter 3 is grinding the second end 22 of the GRIN lens 2 such that angle γ has a particular value that yields a center-wavelength having the desired value. Another method for attaining such filter 3 is by forming the pigtail 1 such that the distances r_1, r_2 yield a center-wavelength having the desired value. The above

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two methods can also be used in combination. Similarly, when the center-wavelength of the filter 3 shifts from its normal center-wavelength, we can according to the offset, adjust the angle γ formed at the joint of the GRIN lens 1 and the filter 3 or at the same time adjust the distances r_1, r_2 respectively from the input and return optical fibers 41, 42 to the center-axis of the pigtail 1 which is also the center-axis of the lens 2 in this embodiment; hence, we can gain the accurate center-wavelength of the multiplexer/demultiplexer in practical application.

[0025] The above method simplifies manufacturing techniques, increases production yield, and decreases costs.

[0026] Thus in another aspect of the present invention, a method of adjusting the waveforms of a filter is provided. Referring to Fig. 4, the method comprises the steps of: measuring the actual center-wavelength of the filter 3; determining a difference between the actual center-wavelength and a desired center-wavelength of the filter 3; determining an angle γ and distances r_1, r_2 that will yield the desired center-wavelength; grinding the second end 22 of the GRIN lens 2 to obtain the determined angle γ and forming the pigtail 1 to obtain the determined distances r_1, r_2; adhering the filter 3 to the ground GRIN lens 2; and integrating the formed pigtail 1 with the combination of the filter 3 and the GRIN lens 2.

[0027] It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure, function and method of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

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